AD-768 194

TRAINING TECHNIQUES FOR RAPID TARGET DETECTION

John R. Powers, III, et al

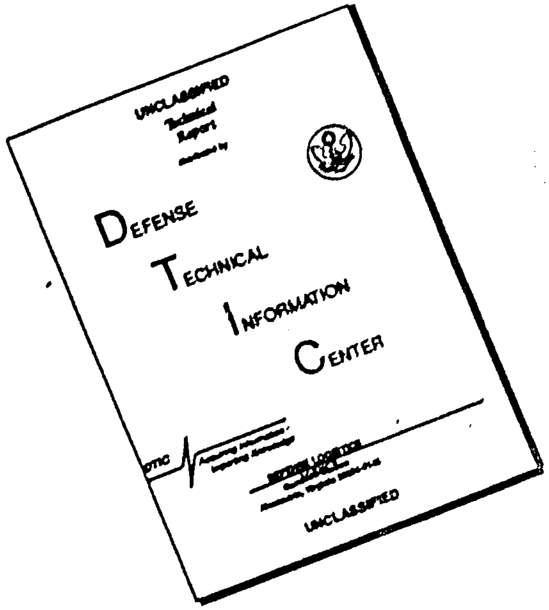
Battelle Memorial Institute

Prepared for:

Assistant Chief of Staff for Intelligence (Army)

September 1973

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

U. S. ARMY RESEARCH INSTITUTE
FOR THE BEHAVIORAL AND SOCIAL SCIENCES

An activity of the Chief, Research and Development

J. E. UHLANER Technical Director	R. A. ROOTH COL, GS Commander

Research accomplished
under contract to the Department of Army

Battelle Memorial Institute

NOTICES

AD-768194

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Battelle Memorial Institute, Columbus, Ohio Army Research Institute for the Behavioral and Social Sciences, Arlington, VA	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

TRAINING TECHNIQUES FOR RAPID TARGET DETECTION

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)

John R. Powers, III, Robert W. Brainard, and Robert E. Abram (Battelle) and Robert Sadacca (ARI)

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
September 1973	~~42~~ 39	2

8a. CONTRACT OR GRANT NO. DAHC 19-67-C-0035 b. PROJECT NO. 2Q662704A721 c. Interpretation Techniques d. e.31	9a. ORIGINATOR'S REPORT NUMBER(S) Technical Paper 242 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Asst Chief of Staff for Intelligence, Washington, D. C.

13. ABSTRACT

Basic to the acquisition of intelligence information from aerial surveillance/reconnaissance sensor products is the ability of the image interpreter to detect (distinguish objects from their background) and correctly identify targets on the product imagery. This publication reports on the evaluation of two systematic search strategies and a "speed-reading" technique for use in training interpreters to search imagery more rapidly and to improve detection accuracy and completeness.

Systematic search strategies for increasing detection completeness and for reducing inefficient search behavior were 1) geometric (structured practice in executing a geometric search pattern) and 2) tactical (structured practice in executing a content-oriented search pattern). To complement the search strategies, a "speed-reading" technique was developed to reduce visual fixation time and expand the size of the perceptual field, through "speeded search"--practice under free search conditions with emphasis on speeded performance. A fourth and control condition allowed practice under free search conditions without emphasis on speeded performance. Eight subjects were assigned to each of the four experimental conditions, and their pre- and post-training target detection performances were compared. An error-avoidance training technique was also tried out.

Training in the two strategies increased the number of target detections over pre-training levels and also increased the number of inventive errors. The speeded search group made the greatest gain in image search speed, close to 200%, which was achieved without loss of accuracy or completeness. The separately studied error avoidance training technique, using an error key approach, substantially reduced inventive

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

Unclassified
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Imagery interpretation						
*Target detection						
*Search strategies						
*Target detection accuracy						
*Target detection completeness						
Inventive errors						
Eye fixations						
Fixation time						
*Speed-reading technique						
Adaptive training						
*Error-avoidance training technique						
Error key						

DD Form 1473

13. Abstract - continued

errors. Error avoidance training used with training in rapid systematic or free search appears helpful in improving detection performance.

Technical Paper 242

AD

TRAINING TECHNIQUES FOR RAPID TARGET DETECTION

John R. Powers, III, Robert W. Brainard, and Robert E. Abram
Battelle Memorial Institute
and
Robert Sadacca
Army Research Institute for the Behavioral and Social Sciences

Abraham H. Birnbaum, Supervisory Project Director

SYSTEMS INTEGRATION & COMMAND/CONTROL TECHNICAL AREA
Cecil D. Johnson, Chief

Submitted By:
Joseph Zeidner, Director
ORGANIZATIONS & SYSTEMS
RESEARCH LABORATORY

Approved By:
J. E. Uhlaner
TECHNICAL DIRECTOR

U. S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES

Office, Chief of Research and Development
Department of the Army
1300 Wilson Boulevard, Arlington, Virginia 22209

September 1973

Army Project Number
2Q662704A721

Contract Number DA-HC-19-67-C-0051
Surveillance Systems

ARI Research Reports and Technical Papers are intended for sponsors of R&D tasks and other research and military agencies. Any findings ready for implementation at the time of publication are presented in the latter part of the Brief. Upon completion of a major phase of the task, formal recommendations for official action normally are conveyed to appropriate military agencies by briefing or Disposition Form.

FOREWORD

The research reported here was accomplished by the Systems Integration and Command/Control Technical Area, Organizations and Systems Research Laboratory of the U. S. Army Research Institute for the Behavioral and Social Sciences. The Institute, established 1 October 1972 as replacement for the U. S. Army Manpower Resources Research and Development Center, unifies in one enlarged organization all OCRD activities in the behavioral and social sciences area, including those conducted by the former Behavior and Systems Research Laboratory (BESRL) and the Motivation and Training Laboratory (MTL).

The Surveillance Systems research program of the Army Research Institute has as its objective the production of scientific data bearing on the extraction of information from surveillance displays and the efficient storage, retrieval, and transmission of this information within an advanced computerized image interpretation facility. Research results are used in future systems design and in the development of enhanced techniques for all phases of the interpretation process. Research is conducted under Army RDTE Project 2Q662704A721, FY 1973 Work Program.

The ARI Work Unit Area, Surveillance Systems, conducts research to develop screening and interpretation methods that will enable an interpretation facility to process rapidly the vastly increased amounts and different kinds of aerial imagery expected through advanced acquisition techniques. The present publication reports on the evaluation of two systematic search strategies and a "speed-reading" technique for use in training interpreters to search imagery more rapidly and to improve detection accuracy and completeness.

ARI research in this area is conducted as an in-house research effort augmented by contracts with organizations selected as having unique capabilities and facilities for research in aerial surveillance. The present study was conducted jointly by personnel of the Army Research Institute and the Battelle Memorial Institute, Columbus Laboratories, Columbus, Ohio.

J. E. UHLANER
Technical Director

TRAINING TECHNIQUES FOR RAPID TARGET DETECTION

BRIEF

Requirement:

To evaluate experimental techniques for training interpreters to search imagery more rapidly and to improve detection accuracy and completeness.

Procedure:

Systematic search strategies were devised for increasing the completeness with which images are searched and for reducing inefficient search behavior. To complement the search strategies, a "speed-reading" technique was developed to reduce visual fixation time and expand the size of the perceptual field. Four experimental training variations were evaluated: 1) a geometric search strategy--structured practice in executing a geometric search pattern; 2) a tactical search strategy--structured practice in executing a content-oriented search pattern; 3) speeded search--practice under free search conditions with emphasis on speeded performance; and 4) a control condition--practice under free search conditions without emphasis on speeded performance. Pre- and post-training target detection performance of the eight subjects assigned to each of the four experimental conditions were compared. An error-avoidance training technique was also tried out.

Findings:

Training in the geometric and tactical search strategies increased the number of target detections over pre-training performance. However, increase was at the expense of increased inventive errors. The greatest gain in image search speed was made by the speeded search group. This gain in speed--close to 200%--was achieved without degradation of other aspects of performance. In a separate study, an error avoidance training technique using an error key approach yielded substantial reduction in inventive errors.

Utilization of Findings:

Error avoidance training in conjunction with training in rapid systematic or free search appears helpful in improving detection performance. A next step is to determine whether the gains in speed and accuracy are maintained over a period of time and to what extent additional training with the techniques can further enhance performance.

TRAINING TECHNIQUES FOR RAPID TARGET DETECTION

CONTENTS

	Page
CONTEXT OF STUDY	1
OBJECTIVE AND GENERAL APPROACH	1
SUBJECTS AND EXPERIMENTAL DESIGN	3
IMAGERY	3
EXPERIMENTAL PROCEDURES	5
Familiarization with the Imagery	5
Pre-Training Performance Measure	5
Three-Part Cyclic Training	6
Post-Training Performance Measurement	9
DEPENDENT VARIABLES	9
RESULTS	10
DISCUSSION	13
CONCLUSIONS	16
APPENDIXES	19
DISTRIBUTION	36
DD Form 1473 (Document Control Data R&D)	39

TABLES

Table 1. Image parameters 4

2. Pre-training and post-training performance means 11

3. Adjusted post-training means and significant mean differences (Scheffe's test) 12

4. Summary of the covariance analyses 14

FIGURES

Figure 1. Experimental design 4

CONTEXT OF STUDY

Tactical commanders require accurate and timely intelligence regarding the disposition and activity of enemy forces. A prime source of this intelligence is imagery acquired by reconnaissance systems. Close and almost continuous surveillance of enemy forces provides a great volume of reconnaissance imagery and places severe demands on image interpreters who must convert raw image information into intelligence information. The interpreter's task is especially demanding because of the requirement for complete, accurate, and rapid interpretation. : difficulty of his task increases with each advance in sensor/platform performance.

One of the basic tasks of the interpreter is searching imagery for targets. All subsequent identification and analysis activity is based on detection of the targets. The need for improving this facet of interpretation is evident from previous research regarding the search and target detection performance of interpreters. Collectively, this research shows that experienced interpreters make some or all of the following errors:

Fail to detect a surprisingly high proportion of targets.

Falsely report as targets many natural terrain features and man-made artifacts.

Fail to search all pertinent areas of the image.

Search some areas repeatedly and redundantly.

Relax or even stop searching after detecting one or two targets.

Devote considerable time to insignificant features in the image.

Fixate on areas in the image for unnecessarily long periods of time.

The objective of the present research was to devise and evaluate training techniques for improving the performance of interpreters in searching imagery and detecting targets.

OBJECTIVE AND GENERAL APPROACH

The alternative search strategies developed for the experiment were designed to reduce inefficient search behavior and to increase the completeness with which images are searched. The search and detection process was viewed as a sampling operation consisting of a series of eye fixations.

The sequence of eye fixations forms a scan pattern that is controlled by the search strategy used by the interpreter. Two directed search strategies were devised: 1) a systematic geometrical scan pattern and 2) a "tactical" pattern based on image content and the likely location of targets. Both strategies were designed to direct the sequence of fixation points and were controlled by visual aids and instructions to the interpreters.

The geometric scan pattern was designed to insure that all areas of an image are searched. The pattern adopted used the familiar left-to-right, top-to-bottom scanning technique used in reading textual material. The geometric strategy was independent of image content. The tactical strategy was designed to concentrate search on the most probable areas of target location using tactically significant features in the image itself as guides. Interpreters were instructed to scan lines of communication--roads, rivers, trails, valleys, and ridges--along which targets move or are temporarily located. Particular attention was to be paid to points of congestion or change along communication lines (e.g., junctions, loading points, fords). After all possible lines of communication had been searched, the tactical strategy required the interpreter to examine features such as areas adjoining man-made structures, pronounced terrain changes, and areas just below the crests of ridges.

To complement the search strategies, a speeded search technique was developed for reducing visual fixation time and for expanding the effective size of the interpreter's perceptual field (the area within which targets can be reliably detected in a single eye fixation). The speeded search technique involves progressively increasing the size of exposed image segments, while shortening the time allowed for viewing the segments. Tachistoscopic illumination of the stimulus materials (aerial photographs) was used to control both segment size and duration. All three experimental techniques forced the interpreter to continue his search activity following the detection of each target and served to inhibit return to previously searched image areas.

These techniques--systematic search strategies and speeded search--were structured to form an integrated "training-transfer" regimen. Under this regimen, the interpreter first detected targets in image segments under tachistoscopic control conditions; he then used visual aids to search an entire image; and finally, he searched an image without use of any aids. These three steps were repeated cyclically, segment size and duration of exposure interval being varied as a function of each interpreter's individual performance. This regimen provided the interpreter with experience in integrating the separate subtasks and in transferring the skills acquired to realistic interpretation conditions where visual aids would not be available.

In addition, a training technique designed to reduce the number of false positives (inventive errors) during search and target detection was tried out. In this technique, commonly made inventive errors are described to the interpreter and practice is given in avoiding such errors. The training procedures and results of the study are described in Appendix A.

SUBJECTS AND EXPERIMENTAL DESIGN

The 32 recent graduates of the Army Image Interpretation Course at Fort Holabird, Maryland who served as subjects for this experiment were divided into four experimental groups of eight men each. Detection performance for the four experimental groups (geometric search, tactical search, unaided search, and control) was evaluated. Subjects in each group were randomly assigned to two subgroups of four interpreters each. One matched set of images was administered to subgroup 1 to obtain measures of pre-training performance and the other set was administered as the post-training measure. Order of administration of image sets was counterbalanced for subgroup 2. Figure 1 shows the basic experimental design for the experiment.

IMAGERY

The imagery used throughout this study was selected from the ARI film library and was acquired at one of the following areas: Camp Drum, New York; Fort Sill, Oklahoma; and Yakima Firing Range in Washington State. The general characteristics of the selected imagery were as follows:

Conventional (optical) positive transparencies

9-inch by 9-inch format

Little or no overlap between frames

Acquired under daylight, clear weather conditions

Vertical or near-vertical orientation

The image parameters measured for use in the study and the values of these parameters are presented in Table 1.

The images were split into three sets. Two sets of 32 images each were matched with respect to the image parameters and were used for performance assessment. The third set (72 images) was used during the training sessions.

EXPERIMENTAL CONDITION		Sub-Groups	Session 1 (Pre-Training)	Session 2 (Post-Training)
	Geometric Search	1	X	Y
		2	Y	X
	Tactical Search	1	X	Y
		2	Y	X
	Speeded Search	1	X	Y
		2	Y	X
	Control Search	1	[illegible]	Y
		2	Y	X

X and Y are matched image sets

Figure 1. Experimental design

Table 1

IMAGE PARAMETERS

Image Parameter	Range	Median	Mean
Scale	1560-6400	2900	3200
Quality [a]	1- 4	3	3
Complexity [b]	0-98	48	46
No. of Targets Per Image [c]	0-41	10	12

[a] Overall quality, based on a consensus judgment by expert interpreters

1 : poor 2 : fair 3 : good 4 : very good

[b] The percentage of total image area containing vegetation

0% : least complex 98% : most complex

[c] Target content consisted primarily of trucks, tanks, tents, and trailers

EXPERIMENTAL PROCEDURES

For each of the four groups in the experiment (geometric search, tactical search, speeded search, and control), the experimental procedures consisted of the following sequential steps: 1) familiarization with the imagery, 2) pre-training performance measure, 3) three-part cyclic training, and 4) post-training performance measure.

Familiarization with the Imagery

This step was the same for all groups and was directed toward familiarizing subjects with the general characteristics and content of the imagery used throughout the experiment--image scale and quality, types of target present, and features of the target background.

For each of 40 annotated images used in this phase of the study, each subject was required to perform several tasks: 1) estimate the total number of annotated targets not normally detectable with unaided vision, 2) search for nontargets that were not annotated but that looked like targets, i.e., confusable objects, and 3) for the remaining targets, which were annotated and detectable, estimate the number of vehicles, weapons, fortifications, aircraft, and miscellaneous targets present.

A two-minute time limit was set for each image. During this time, each subject recorded the estimated number of annotated targets which could not be detected without aids and the number of detectable targets in each of five target categories (vehicles, weapons, fortifications, aircraft, and miscellaneous).

Pre-Training Performance Measure

Measurement of pre-training performance was the same for all groups. For each of 32 unannotated images, the subject was required to detect and mark all tactical targets without using any visual aids such as magnifiers. Marking was done by placing a dot in the center of each target on a transparent acetate overlay. Subjects were instructed to search rapidly and thoroughly and to specify as targets only those objects for which they had 90 percent or more confidence. They were allowed two minutes per image.

Each subject's performance was scored for completeness and time taken per image. These indices were used to match groups for assignment to the geometric and tactical groups. For the remaining conditions--speeded search and control--separate and unmatched groups of subjects were used.

Three-Part Cyclic Training

Subjects were administered 34 cycles of practice during this phase of the experiment. Each cycle consisted of three parts, two images being used in each part for a total of 72 different images--12 sets of six images each. A different set was used for each cycle and repeated every 12 cycles.

Geometric Search and Tactical Search Groups. Training for both groups dealt with individual visual fixations, or glimpses. For example, if glimpse size is to small, the interpreter tends to use an unnecessarily large number of visual fixations; if the duration of the glimpse is longer than necessary, critical search time is wasted. In addition, eye movement between two successive glimpses needs to be controlled so that all areas are viewed and there is little or no overlap between areas glimpsed. The three parts of each training cycle were designed to provide integration of field-expansion and glimpse time reduction with the search strategy.

Part A. The first part of each cycle was directed toward 1) increasing the image area seen with a single glimpse, 2) reducing glimpse time, 3) reducing time between glimpses, 4) developing a controlled interfixation distance, and 5) developing a systematic sequence of glimpses. For each of two images, the subject was required to report whether the image segment contained one or more targets. An image was mounted in the segment illuminator[1] and glimpse parameters were set: segment illumination time (200 or 100 milliseconds), segment size (7, 11, or 16 degrees), and intersegment intervals (1.5, 1.0, or 0.5 seconds)[2]. Segments of a horizontal or vertical strip of imagery were illuminated in sequence automatically. For geometric search, the sequence was always horizontally from left to right. For tactical search, the sequence alternated between vertical and horizontal presentation. Following the presentation of each strip, the subject was told the number of his target reports that were correct. Another strip was then aligned on the segment illuminator and the sequencing process continued until the entire image was searched.

1/ See Appendix B for detailed description of the segment illuminator and other experimental apparatus.

2/ See Appendix C for a description of the preliminary experiments conducted to determine appropriate parametric values for use in the main experiment.

Part B. In the second part of each cycle, the subject was given practice in scanning an entire image and in applying both the glimpse technique and the search strategy used in Part A--either geometric or tactical. The subject's task was similar to the searching, detecting, and target-marking task of the pre-training session. However, he was provided with a grid overlay that divided the entire image into small segments (geometric search) or outlined the portions of the image having tactical features (tactical search). Cell size of the grids was the same as in the segment used in Part A (7, 11, or 16 degrees). The subject was required to complete his task within one of three time limits (120, 78, or 30 seconds). To obtain performance feedback, the subject scored the first of the two images, using a template on which the location of all targets was shown. Number of inventive errors and number of correct detections, as well as the time taken to search each image, were recorded.

Part C. The third part of each cycle consisted of training in scanning and applying the glimpse technique but without the support of visual aids. The subject's task was identical to that in the pre-training sessions, except that the subject self-scored both images, giving himself immediate feedback. Scores were used as the basis for changing the speed/segment size parameters of Part A for the next cycle. The time used, number of inventions, and number of correct detections were recorded for each of the two images in this part.

Speeded Search. For the speeded search group, the three parts in each cycle provided training in free search with emphasis on speed.

Part A. The first part of each cycle gave training in speeded search for targets under task conditions analogous to those of the geometric search and tactical search groups. For each of two images, the subject was required to search and detect targets as quickly and as accurately as possible within one of the three time limits (120, 78, and 30 seconds), depending upon the individual interpreter's previous performance levels. The subject reported the location of each target by giving its horizontal and vertical grid coordinates. The size of the cells in the grid, which covered the entire image, were specified prior to search (7, 11, or 16 degrees).

Part B. The second part of each cycle gave practice in speeded search. The task for each of the two images was identical to the pre-training performance measure, with one exception: A time limit of 120, 78 or 30 seconds was set as a function of the interpreter's level of performance. The actual time taken for each image was recorded and provided as immediate feedback to the subject.

Part C. The third part of each cycle provided practice in speeded search with a fixed time limit (120 seconds). The task and procedures for each of the two images in this part were identical to those used in the pre-practice session.

Control Group. For the control group, the three parts in each cycle provided only familiarization with the imagery and practice with the detection task. The type and quantity of imagery searched by the control group were identical to that searched by the other groups.

Part A. For each of two images, the subject was required to search and detect targets within a fixed time limit (120 seconds). The subjects reported the location of each target by giving its horizontal and vertical grid coordinates. Size of the cells in the grid was fixed (16 degrees).

Parts B and C. Task and procedures for each of the four images were identical to those used in the pre-practice session.

Adaptive Training. For the geometric search, tactical search, and speeded search groups, the adaptive training procedure used permitted a change in the speed and/or segment size parameters based on the individual interpreter's performance. The procedure allowed each subject to master the speed/segment-size conditions at his own pace. The adaptive procedure consisted of the following steps for each subject in the geometric and tactical groups:

1. A completeness criterion was established, equal to the subject's pre-training completeness performance.

2. A time criterion was established, equal to the subject's lowest mean time on any two preceding consecutive cycles (Part C).

3. If the subject's time or completeness performance during Part C was equal or better than the criterion, the subject was advanced to the next most difficult set of speed and segment-size parameters. If it was less than 25 percent below the criterion, the subject was given the option to advance to the next most difficult set of speed and segment-size parameters. If it was more than 25 percent below the criterion, the subject was held at the current parametric values. Two consecutive "holds" returned the subject to the preceding (easier) set of parametric values. After three consecutive holds, the time criterion was eased by reducing it to the next-to-the-lowest mean of any two preceding consecutive cycles.

The adaptive training procedure for the speeded search group was the same as the geometric and tactical groups, with two exceptions: 1) only a single criterion, time, was used, and 2) segment size referred only to the cell size in the grid coordinates of Part A.

Subjects in the geometric search, tactical search, and speeded search groups all had the same parametric values for the first two cycles of training. For the third cycle, time parameters were automatically reduced. For all remaining cycles, changes in the parameters were made on an adaptive, individualized basis. The schedule of changes in the parameters was as follows:

Cycle	Segment Size (deg.)	Inter-Fixation Interval (sec.)	Glimpse Time (msec.)	Time Limit for Each Part B Image (sec.)
1 and 2	7	1.5	200	120
3	7	1.5	100	120
Adaptive	11	1.5	100	78
"	11	1.0	100	78
"	16	1.0	100	30
"	16	0.5	100	30

The 120- and 78-second time limits for Part B images were the theoretical times required to search using the corresponding segment sizes, intervals, and glimpse times. For the 30-second limit, additional time was added to the theoretical time allowed for marking detected targets.

Post-Training Performance Measurement

This step was the same for all groups and was directed toward an assessment of performance following training. The task and procedures for each of 32 unannotated images was the same as those used in evaluating pre-training performance. In addition, subjects in the geometric search, tactical search, and speeded search conditions were urged to use the techniques which they had learned during the three-part cyclic training.

DEPENDENT VARIABLES

The interpreters' task in the pre- and post-training sessions was solely one of detecting targets. Although some level of recognition or even identification may actually have been involved in target detection, only target versus nontarget discrimination was required of the interpreters. For this reason, only indices of target detection were used in assessing and comparing subject performance under the four experimental conditions.

Of the possible indexes of target detection performance, the total time devoted to the search and detection function was of prime importance. Both the systematic search strategies and the speeded search techniques were aimed at reducing the time required for search and detection.

A second performance index of special relevance was completeness--the proportion of total targets detected. Use of this index was based on a prime objective of the geometrical and tactical search strategies--to insure that all areas of the image were searched. With more comprehensive search of the image, number of targets detected would be expected to increase.

A detection accuracy index, defined as the proportion of total detection responses that were correct, was also used.

The completeness and accuracy indexes do not, of course, reflect all aspects of interpreter performance; they do not isolate inventive errors (nontargets reported as targets) or omissions (failure to report targets). These two errors were additively combined to form an overall error index. However, in order to provide an indication of the separate contribution of these two error sources, the inventive error component of the overall error index was treated as a fifth performance index.

The following performance indexes were used in the covariance analysis:

1. Time: number of seconds devoted to an image

2. Completeness: proportion of total targets detected (number of correct detections divided by the number of targets)

3. Accuracy: proportion of total detection responses that were correct (number of correct detections divided by the number of detection responses)

4. Overall Error: number of inventions plus number of omissions

5. Inventive Errors: number of nontargets reported as targets.

RESULTS

Table 2 gives pre-training and post-training performance data for the four experimental groups on each of seven performance indexes. Two indexes not included in the covariance analysis are reported: total number of detections made and number of correct detections. Each mean value reported is based on the performance of eight subjects with each subject analyzing 32 images. Results given in this paragraph depend solely upon descriptive statistics and do not include tests of significance. Subjects in the systematic search groups--geometric and tactical--reported a greater mean

Table 2

PRE-TRAINING AND POST-TRAINING PERFORMANCE MEANS

Performance Index	Experimental Groups							
	Geometric Search		Tactical Search		Speeded Search		Control	
	Pre-Training	Post-Training	Pre-Training	Post-Training	Pre-Training	Post-Training	Pre-Training	Post Training
Total Detections[a]	10.64	13.17	10.31	16.87	11.37	9.97	10.85	9.53
Correct Detections[a]	6.98	7.02	6.89	7.18	7.13	6.19	6.21	5.79
Time (Minutes)	94.20	38.09	85.21	48.12	89.27	31.05	71.26	35.06
Completeness	0.55	0.56	0.55	0.57	0.56	0.50	0.49	0.46
Accuracy	0.67	0.55	0.66	0.44	0.68	0.65	0.62	0.63
Overall Error	9.05	11.51	8.91	14.89	9.51	9.97	10.81	10.34
Inventive Error	3.66	6.14	3.41	9.67	4.25	3.81	4.65	3.72

[a] Not included in the covariance analyses

Table 3

ADJUSTED POST-TRAINING MEANS AND SIGNIFICANT MEAN DIFFERENCES (SCHEFFE'S TEST)[a]

Performance Index	Experimental Groups			
	Systematic Search Methods		Free Search Methods	
	Geometric	Tactical	Speeded Search	Control
Time	32.27	47.98	28.34	43.72
Completeness	0.56	0.57	0.51	0.46
Accuracy	0.54	0.44	0.64	0.65
Overall Error	11.62	15.02	9.99	10.08
Inventions	6.22	9.83	3.74	3.55

LEGEND:

= Significant Mean Differences Between Pairs of Means (α = .10).

= Significant Mean Differences (α = .10)

[a] Scheffe suggests that, because of the conservative nature of this test, α = .10 be used rather than α = .05.

number of both correct detections and inventive errors in the post-training task than they did in the pre-training task. The free search groups--speeded and control--produced opposite results. While subjects in the systematic search groups averaged over 50 percent more total detections in post-training performance than did the free search groups, almost 80 percent of this increment was due to the greater number of inventive errors. Pronounced performance differences between pre- and post-training were found for the time variable, the greatest increase in speed occurring for the speeded search group.

As the four groups differed in their pre-training performance scores, an analysis of covariance was used to adjust the post-training scores (this statistical adjustment permits comparison of post-training data as if all groups had the same pre-training performance level). The resulting adjusted mean values for post-training performance are presented in Table 3, which also shows the results of Scheffe's Test for Multiple Comparisons[3]. Details of selected comparisons are shown in Appendix D. The summary of the covariance analysis is given in Table 4.

For differences between the systematic and free search methods, the analysis indicated that, while training in the use of systematic search strategies resulted in significantly better completeness performance, it also resulted in significantly larger overall error rate, as well as producing more inventive errors. This result is reflected in the significantly better accuracy under the free search conditions. Time differences between the systematic and free search strategies were not significant.

Subjects using the tactical search strategy demonstrated poorer performance than subjects in the speeded search and control groups, as shown by the accuracy, overall error, and inventive error indices in Table 3. Subjects trained using the geometric strategy generally performed at a level between the speeded search and control groups on the one hand and the tactical search group on the other.

DISCUSSION

A major question investigated in the study was the effectiveness of systematic search strategies as compared with free search. The results show that time per image was not significantly different for the two types of search. Subjects in the systematic search groups spent as much time on each image as subjects in the free-search groups. However, subjects in the systematic search groups made over 50 percent more responses

[3]Edwards, A. L. Experimental Design in Psychological Research (Rev. ed.) Pp. 154-156. New York: Holt, Rinehart and Winston. 1963.

Table 4

SUMMARY OF THE COVARIANCE ANALYSES

Performance Index	Source of Variation	Sum of Squares	df	Mean Square	F
TIME	Treatments	1840.0546	3	613.3515	3.61*
	Error	4592.9403	27	170.1089	
	TOTAL	6432.9949	30		
COMPLETENESS	Treatments	.0668	3	.0223	3.54*
	Error	.1714	27	.0063	
	TOTAL	.2382	30		
ACCURACY	Treatments	.2453	3	.0818	4.76**
	Error	.4656	27	.0172	
	TOTAL	.7109	30		
OVERALL ERRORS	Treatments	129.1201	3	43.0400	5.34**
	Error	217.5295	27	8.0566	
	TOTAL	346.6496	30		
INVENTIONS	Treatments	201.2830	3	67.0943	8.33**
	Error	217.4744	27	8.0546	
	TOTAL	418.7574	30		

* Adjusted means significantly different, $P \geq .05$.

** Adjusted means significantly different, $P \geq .01$.

(both correct detections and inventions) than the free search groups, and hence had a higher completeness percentage. Overall response frequency of the search strategy groups was approximately 1.5 times that of the free search groups. However, almost 80 percent of the difference in number of responses was due to the greater number of inventive errors made by the systematic search groups; only 20 percent was due to an increase in the number of correct detections. Thus, while the systematic search groups detected one target more per image on the average than did the free search groups, they also averaged four more inventions per image.

It would appear that while systematic search strategies increase detection completeness, this effect may be outweighed by the large increase in inventive errors. However, if the number of such errors could be greatly reduced, systematic search strategies would be much more effective. Previous ARI research[4] has indicated that error keys designed to alert interpreters to nontargets often identified as targets are effective in reducing inventive errors. A study conducted as part of this effort (Appendix A) verified that this technique reduced inventive errors substantially. Moreover, this reduction was achieved with no decrease in the number of correct detections.

A second major question investigated was the differential effects of the two systematic search strategies on performance. The tactical search strategy was designed to direct the interpreter's attention to clues to the most probable target locations (lines of communication, for example). The geometric search strategy was designed to insure that all areas of the image were searched. Results show that training in the tactical search strategy resulted in significantly more time used, larger overall error, and more inventive errors. The geometric search strategy resulted in somewhat smaller increases in these indexes than did the tactical search strategy.

Some speculative inferences based on the nature of the images and tasks used may shed some light on why the tactical group made more inventive errors than the geometric search group. The imagery was such that the lines of communication were principally roads, mostly unimproved, and tracks made by extensive vehicle use. The roads contained numerous dark patches (caused by puddles, oil, shadows, etc.) which could be confused

---

[4] Martinek, H., and R. Sadacca. Error keys as reference aids in image interpretation. ARI Technical Research Note 153. June 1965. (AD 619 225)

with vehicles. In addition, the tracks themselves frequently produced target-like images. The tactical search strategy might have operated to direct the interpreter's attention to these invention-producing items. Also, this strategy, through its emphasis on searching where targets are most likely to be found, may induce interpreters to respond more readily to dubious cues.

The third major question investigated was the difference between the speeded search and control conditions. Both groups received practice in free search, the speeded search group receiving instructional emphasis on speed and searching within adaptive time limits. Time per image in the speeded search group was somewhat less than in the control group. This result occurred without significant differences in completeness, accuracy, overall error rate, or inventive errors. This finding is particularly encouraging, since the speeded search technique would be easy to implement operationally, requiring only a stop watch in the way of special equipment. The improvement in speed shown by the control group should also be noted; it indicates that merely through intensive practice interpreters can considerably increase their detection speed.

In addition to the three preceding questions, certain ancillary aspects of the adaptive practice techniques used in the study warrant attention. Adaptive procedures were used in conjunction with a technique for making the perceptual task increasingly difficult so that each subject would advance through the material to be learned at a pace commensurate with his ability. For subjects in the geometric search and tactical search groups, considerable improvement was made in the rate at which image segments were scanned. The net result was a reduction in the amount of time per unit area equivalent to seven hundredths of its initial value.

CONCLUSIONS

The experimental findings support the following conclusions:

1. Certain aspects of the image interpreter's detection performance can be enhanced by training in the use of rapid systematic search strategies. The two strategies investigated increased the number of target detections without lengthening the time required per image. However, significantly more inventive errors were made with these strategies than under free search conditions.

2. Of the two systematic strategies investigated, geometric search appeared the most promising. Search detection times were shorter with this strategy than with the tactical search method, and fewer inventive errors were made.

3. Detection performance under free search conditions can be enhanced by adaptive practice and instructional emphasis on speeded search and detection. Subjects in the speeded search group took less time per image than those in the control group. This result was achieved without degradation in the other indexes of performance.

4. Training in inventive error avoidance through use of an error key is effective in reducing inventive errors. A supplementary study indicated that this technique reduced inventive errors two-fold and shortened the time per image by more than 20 percent. The findings of this study, coupled with those of the Martinek and Sadacca study[6], provide substantial evidence for the effectiveness of the error key technique. Using this technique in conjunction with rapid detection training may result in considerable improvement in interpreter detection performance.

5. To determine whether the gains in speed and error avoidance are maintained over a period of time, a longitudinal study would be useful. The need for additional practice to maintain or further enhance detection proficiency also remains to be determined.

---

[6] Martinek, H., and R. Sadacca. Error keys as reference aids in image interpretation. ARI Technical Research Note 153. June 1965. (AD 619-225)

APPENDIXES

Page

Appendix

A. ERROR AVOIDANCE TRAINING TECHNIQUE 21

Tables: A-1. Performance during error-key training 23

A-2. Mean subject performance per image before and after error-avoidance training 23

B. EXPERIMENTAL APPARATUS 25

Figures: B-1. Chip-projection apparatus 26

B-2. Strips and segments in a 9"-by-9" reconniassance photograph 29

C. PRELIMINARY EXPERIMENTS 31

D. SELECTED COMPARISONS USING SCHEFFE'S TEST FOR MULTIPLE COMPARISONS 35

Preceding page blank

APPENDIX A

ERROR AVOIDANCE TRAINING TECHNIQUE

One of the most frequent errors in image interpretation is the reporting of targets where none exist. Even experienced interpreters may report rocks and shadows as targets, or they may confuse unfamiliar civilian objects with military targets. The reduction of such errors was the aim of the training technique investigated in this small-scale experiment.

Martinek and Sadacca[1] have developed a key which is designed to alert interpreters to errors commonly made in target/non-target discrimination. This error key has been successful in reducing the number of false positive detections (inventions) in tactical reconnaissance imagery. The present study further investigates the effectiveness of the error key approach.

In the development of the error keys used in the present experiment, inventive errors made by interpreters over a range of images were analyzed. Expert image interpreters, acting collectively, inferred the probable basis of these errors. From these data, five major error categories were identified:

- Inferring the current presence of vehicles from old track activity
- Misinterpreting unusual shadow patterns as military targets
- Attributing target-like features to unfamiliar objects
- Confusing regular-shaped treetops with targets
- Interpreting natural terrain features (e.g., rock formations) as targets

After these major categories were identified, tactical reconnaissance imagery was assembled which contained nontarget objects and situations of the type that could lead to false detections. The imagery was divided into three sets. A small initial set was used to familiarize trainees with inventive errors typically made. Objects were annotated on a second comparable set. Associated with each annotated object was a short description of the type of error commonly made and the probable reasons for the error. The trainees read the pertinent description after first deciding whether the annotated object was a target.

---

[1] Martinek, H. and R. Sadacca. Error keys as reference aids in image interpretation. ARI Technical Research Note 153, June 1965. (AD 619 225)

Preceding page blank

Following these familiarization sessions, the instructional unit provided training in using the error key information with 80 images, containing approximately 200 annotated targets and nontargets. Subjects used the error keys to determine whether annotated objects were targets or nontargets. The types of annotated objects used in the practice sessions are presented in Table A-1, along with the average percentage of correct discriminations made by the subjects.

To assess the effectiveness of the error avoidance training, matched sets of 27 unannotated images were presented to the experimental subjects before and after administration of the instructional unit. In both sets, the subjects' task was to detect all targets in the imagery. Subjects were eight Army image interpreters with a minimum of two years of field experience. Their before and after training performance is shown in Table A-2. The data indicate that inventive errors (mean number of inventive errors per subject per image) were reduced twofold[a], while detection completeness was unchanged. The reduction in the search-detection time suggests that error avoidance practice also decreased the time required for deciding if an object was a target or nontarget.

Additional data were collected from a small sample of interpreters with no field experience. In the latter case, the number of inventions was reduced by 90% over pre-training performance, (from 3.20 to .031, per subject/image).

On the basis of the findings from this study, coupled with those from the study of Martinek and Sadacca, it appears that the error key is an effective technique for reducing inventive errors.

---

[a] Difference is significant at $P < .01$.

Table A-1

PERFORMANCE DURING ERROR-KEY TRAINING

Item	Number of Occurrences	% Correct Decisions
Targets		
Vehicle	35	88%
A.P.C.	3	100%
Tank	9	79%
Tents	6	58%
SP Gun	4	81%
Trailer	1	62%
Structure	1	88%
	59	79%
Non-Targets		
Puddle	7	96%
Rock	28	92%
Vegetation; bushes, trees, etc.	56	94%
Shadow	26	97%
Tracks	27	94%
	144	95%

Table A-2

MEAN SUBJECT PERFORMANCE PER IMAGE BEFORE AND AFTER ERROR-AVOIDANCE TRAINING (N= 8 image interpreters)

Performance Index	Before	After
No. of Inventions	2.3	1.0
Completeness	42.8%	42.6%
Time	58.7 Sec.	45.8 Sec.

APPENDIX B

EXPERIMENTAL APPARATUS

The principal experimental apparatus used in the study were an image chip projector, an image segment illuminator, and modular programming logic.

Image Chip Projector

The function of this device is to rear-project single segments or "chips" of reconnaissance transparencies for very short exposures. Standard 9"-by-9" reconnaissance transparencies were selected for overall quality, contrast, and target distribution. Segments of these transparencies were cut out to fit standard 35 mm, 2-inch glass-mount slides. These slides, grouped by scale, were then placed in slide trays for use in the projector. The chip-projection apparatus, shown in Figure B-1, consists of the following components:

- a Kodak "carousel" slide projector (model B650)[1]
- a 4-inch focal-length lens, adjusted to give a one-to-one slide-to-image projection ratio
- an electro-mechanical high-speed shutter
- a neutral-density light filter
- a ground-glass rear-projection screen
- a mask to allow a pre-determined area of the projected image to be viewed
- a restraining bar to control the interpreter's viewing distance

---

[1] Trade names are used only in the interest of precision of reporting. Their use does not constitute endorsement by ARI or by the Army.

Preceding page blank

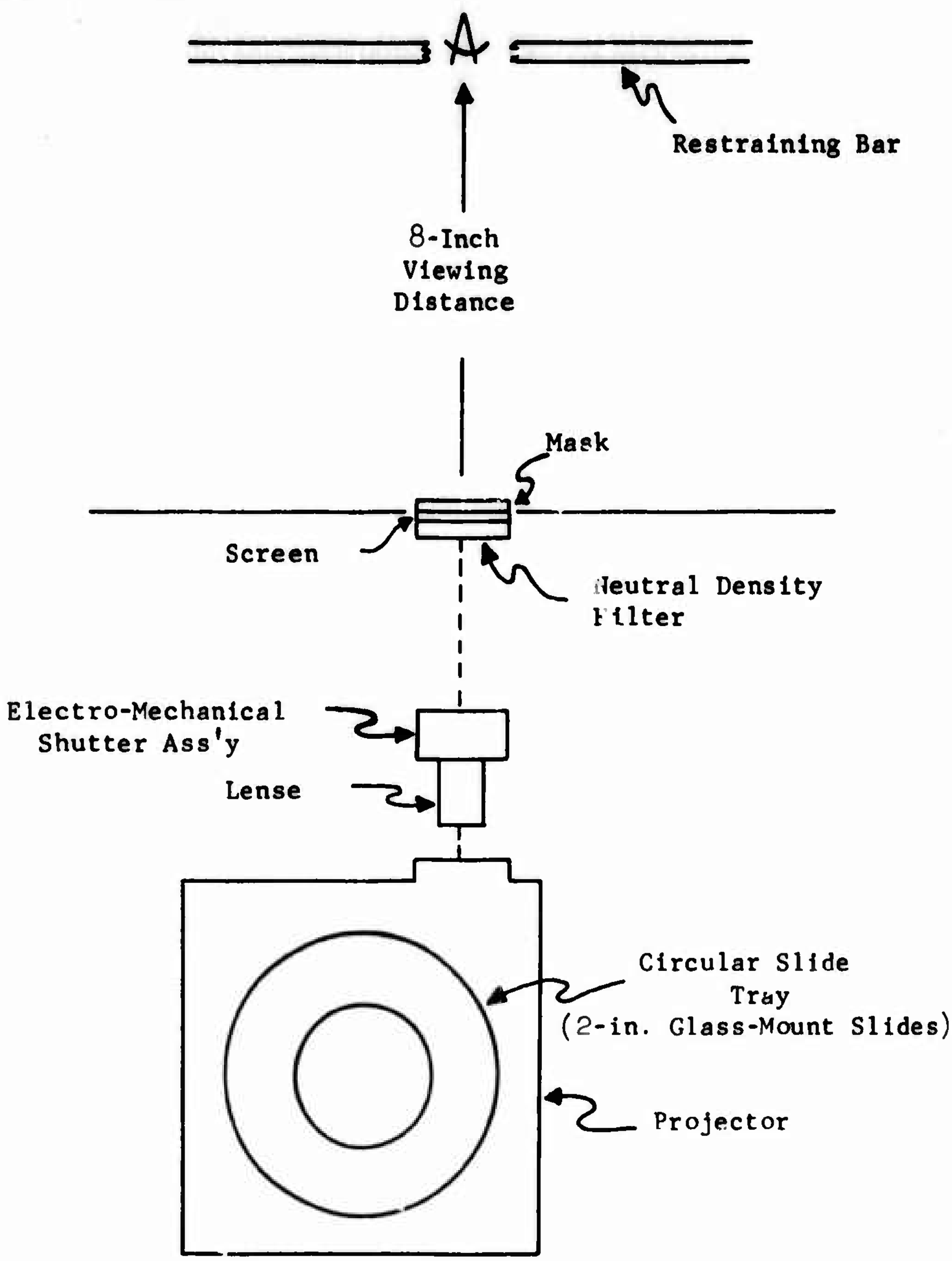


Figure B-1. Chip-projection apparatus *(top view, approximately ¼ size)*

In operation, the advancement and projection of slides is controlled by the experimenter through modular programming logic. Two steps are involved in the projection of each chip: 1) The experimenter signals the programming logic to project a slide (through the electro-mechanical shutter) for a preset duration; 2) depending upon the subject's response, the experimenter may either a) reproject the current chip for an extended period of time or b) signal the logic to advance to the next chip and continue with step 1.

Image Segment Illuminator

The function of this device is to illuminate small segments of images under controlled exposure conditions. The device was used in the present study in connection with perceptual field expansion and short exposure practice. In combination with the modular programming logic, this apparatus provides control over the following parameters: size of the image segment projected, time allowed for viewing the segment, and time allowed between presentation of two successive segments to make the target/non-target decision.

The device, which was specially designed to use conventional reconnaissance imagery, illuminates the full width of a 9-inch reconnaissance image in a series of horizontal segments. The size of each segment is equal to the desired field size in height and width. Viewing time is controlled by rear-illuminating each segment for the desired exposure duration. Decision time is controlled by the inter-segment illumination interval. A combination of modular programming logic and specially designed logic-to-illuminator interface allows pre-setting the parametric values and automatic sequencing through the segments of each horizontal strip.

The following steps constitute the operational aspects of the device as it was used in the study:

- The image-segment size is selected.
- A 9"-by-9" transparency is placed on the illuminator.
- The sequence is begun:

    1. The first segment is illuminated (exposure time).
    2. The subject verbalizes whether or not a target is present (decision time).
    3. The next segment is illuminated (exposure time).

Steps 2 and 3 continue for the rest of the segments in the strip. Then:

- The image is moved upward so that a different horizontal strip of segments will be viewed.
- This process continues, segment-by-segment, until the complete image has been viewed.

Figure B-2 shows the relationship of the strips and segments in a 9"-by-9" reconnaissance photograph.

Modular Programming Logic

The modular programming logic[a] consisted of logic gates, timers, counters, and input/output converters in modular form. "Programs" were created by plug-wiring the modules together to perform the desired functions. For this study, programs were plug-wired to perform the following functions:

- Control the exposure duration of a chip or image segment
- Regulate inter-segment exposure interval
- Sequence of image segments (through a specially designed logic-to-illuminator interface).

---

[a] Manufactured by the Grason-Stadler Company, West Concord, Mass.

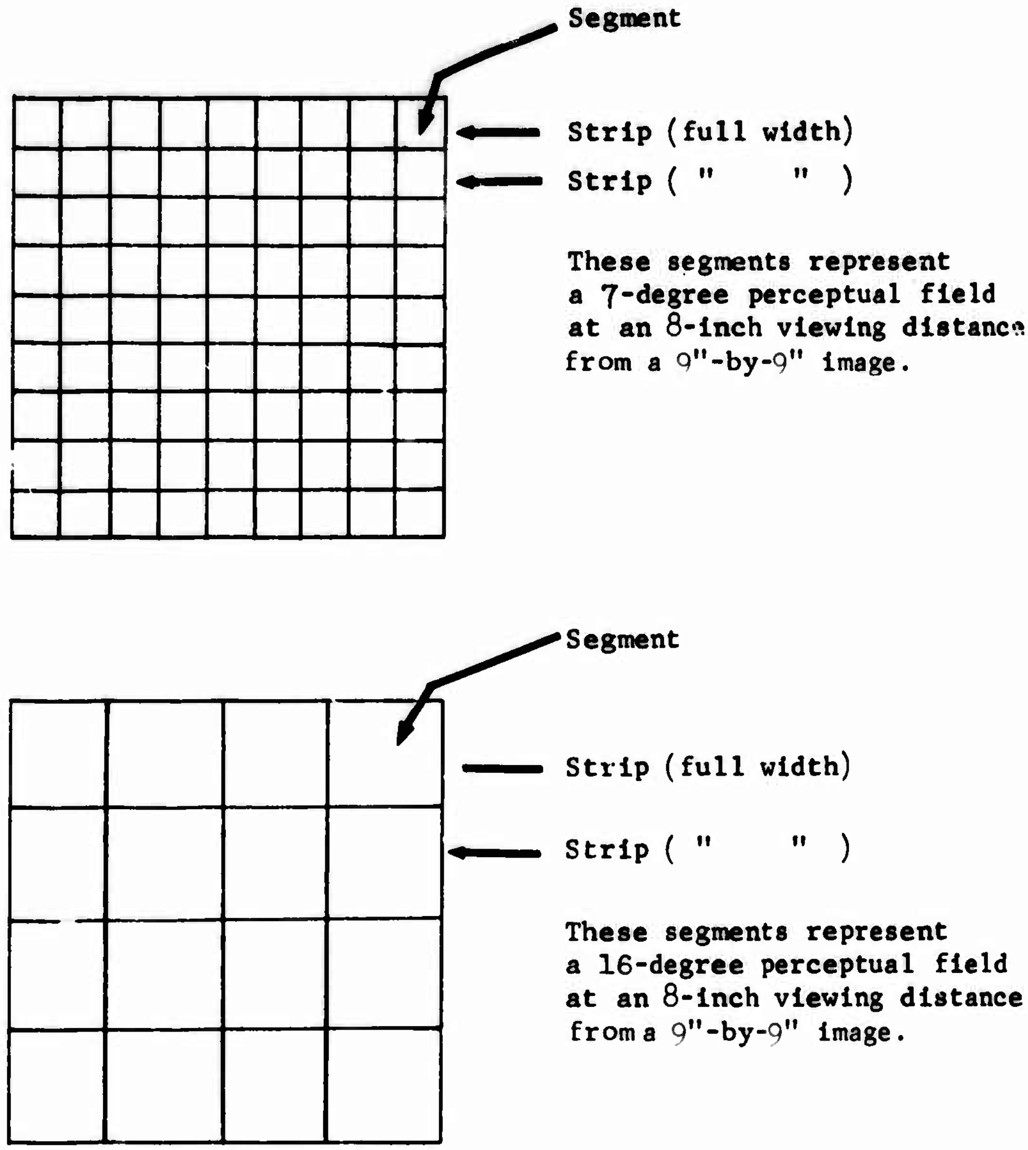


Figure B-2. Strips and segments in a 9"-by-9" reconnaissance photograph *(¼ scale)*

APPENDIX C

PRELIMINARY EXPERIMENTS

Previous research was of little value in determining many of the parametric values and procedures to be used in the present study. The absence of such information necessitated the conduct of a number of small-scale experiments to make the proper selection for the main investigation. Some of the questions that had to be answered were:

What is the shape and size of the perceptual field of an interpreter engaged in target detection?

How much does this perceptual field vary between interpreters?

Within what range can the perceptual field be expanded?

How short can the glimpse time be made without seriously impairing target detection performance?

What techniques are effective for integrating expansion of the visual field, reduction of glimpse time, and systematic application of a search strategy?

Measurement of the Perceptual Field

The first preliminary experiment was designed to measure the size and shape of interpreters' perceptual fields. Subjects were required to look at a fixation point in the center of a small segment or "chip" of imagery, and indicate the location of a target. Eye movement by the subject was prevented by tachistoscopically controlling rear-illumination of the image chip so that the exposure duration was not long enough to allow multiple fixations. For each chip, a single tactical target was located along an imagery radius at a preselected number of degrees from the fixation point. For a set of image chips the location of a target in each image chip was specified in terms of different orientations from the fixation point along several different radii. This technique provided a direct point-for-point mapping of the subject's perceptual field for target-background discrimination (target detection). A "50% correct target detections" was selected as the criterion for delimiting the size of the perceptual field.

As a result of the experiment, 1) the perceptual field size was set at approximately 6 degrees[1] (a large decrement in target detections was

[1] Angular subtense of the perceptual field

Preceding page blank

obtained between 6 and 9 degrees); 2) the field shape was made approximately square; and 3), the field size differed by a factor of approximately two between subjects having the largest and smallest perceptual fields.

Field, Time, and Strategy Evaluation

The next experiment was an evaluation of different procedures to increase the effective perceptual field, reduce glimpse time, and teach a systematic search strategy. An additional and equally important objective was to discover the limits of perceptual field expansion and glimpse-time reduction.

Subject performance was evaluated following each of two steps: 1) training in field expansion and glimpse-time reduction, and 2) training in systematic search with aids.

Training in field expansion and glimpse-time reduction was implemented by tachistoscopically rear-projecting chips of reconnaissance imagery which were masked to control the available field size[a]. The subject's task was to report the number of targets shown in each chip. Following each erroneous response, the subject was informed of the actual number of targets within each chip. The field size and glimpse time were made more demanding as a function of subject performance. Field sizes of 3, 5, 7, and 9 degrees and glimpse times of 500, 300, 200, and 100 milliseconds were used during this experiment.

Training in systematic search with aids was implemented by instructing the interpreter to use a boustrophedon scan pattern (alternately scanning from right to left and then left to right) and by providing him with a gridded overlay to guide his search through the reconnaissance image.

The results of this experiment were:

1. All subjects were able to reach the maximum field size (9 degrees) and minimum glimpse time (100 milliseconds) with only a moderate amount of practice.

2. Subject performance using the smaller field sizes (3 and 5 degrees) and longer exposure time (500 milli-seconds) was no better than performance at the next most difficult parametric values.

---

[a] A detailed description of the chip-projection procedures is given in Appendix B.

3. Performance following systematic search with aids was no better than performance prior to training.

4. Subjects reported difficulty in applying the glimpse technique while practicing systematic search. They attributed this difficulty to the temporal remoteness of the field expansion and glimpse-time reduction training.

Based on these findings, the smaller values of the perceptual field parameters (3 and 5 degrees) were eliminated and the range extended to 11 degrees. Also, the longest glimpse time, 500 milliseconds, was eliminated.

To achieve the maximum effectiveness of the field expansion and glimpse-time reduction in conjunction with image search, a procedure was devised to integrate each of these components into a unified training regime.

Integrated Training Procedure

Finally, a pilot study was conducted under conditions similar to those which were planned for the main experiment. The study incorporated all of the refinements indicated during earlier experimentation. Of primary interest were the integrated training procedure and a procedure to control both the time between glimpses and the interfixation distance. The results, in summary, showed that:

1. Field sizes of 9, 11, and 16 degrees would be more effective than the 3, 5, and 9 series in increasing the perceptual field.

2. Glimpse times of 200 and 100 milliseconds were adequate for target-background discrimination.

3. Interfixation times of 1.5, 1.0, and 0.5 seconds were adequate for the reporting of detected targets.

4. The integrated training procedure provided an effective means of combining the glimpse and search components.

The parameters and procedures were subsequently adopted for use in the main experiment.

APPENDIX D

SELECTED COMPARISONS USING SCHEFFE'S TEST FOR MULTIPLE COMPARISONS

Comparison	Time	Completeness	Accuracy	Overall Error	Inventive Error
Geometric (G) vs Tactical (T)	2.40	< 1	1.60	2.39	2.54
Geometric (G) vs Speeded (S)	< 1	1.42	1.55	1.15	1.74
Geometric (G) vs Control (C)	1.75	2.66*	1.64	1.08	1.88
Tactical (T) vs Speeded (S)	3.01**	1.67	3.15**	3.55**	4.29**
Tactical (T) vs Control (C)	< 1	2.90*	3.24**	3.48**	4.43**
Speeded (S) vs Control (C)	2.36	1.24	< 1	< 1	< 1
(G + T) vs (S + C)	< 1	3.05**	3.39**	3.28**	4.36**
(G + T + S) vs (C)	1.41	2.78*	2.03	1.83	2.63*

* Adjusted means compared significantly different, $P \leq .10$.

** Adjusted means compared significantly different, $P \leq .05$.

Preceding page blank